The Effect of Intramedullary Reaming on a Diaphyseal Bone Defect of the Tibia

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Animal models have suggested that unreamed and limited reamed intramedullary nails provide improved healing of tibia fractures without bone defects compared to extensively reamed nails.1,2 The purpose of this study was to relate the extent of reaming to bone formation occurring around a critical sized defect in the tibia. The extent of reaming of the intramedullary canal was dependent on the cross-sectional area of the tibia as all tibiae were reamed with the same 7.0mm diameter reamer. Two different treatment groups were examined based on treatment of the defect site: 1) the defect site was left empty, or 2) the defect site was treated with an iliac crest cancellous autograft. The empty group simulated the acute trauma situation while the autograft group simulated the definitive treatment of the defect.

Methods
Permission for the use of 11 mixed breed canines was obtained from the St. Michael’s Hospital Animal Care and Ethics Committee (Toronto, ON, Canada). An 8.0mm diaphyseal tibia defect was created in a canine model. All tibiae were reamed to 7.0mm and fixed with a 6.5mm statically locked intramedullary nail. The defect was either left empty (N=5) or treated with iliac crest autograft (N=6).

Fluorescent markers were given at successive time periods: calcein green at 6 weeks, xylanol orange at 9 weeks, and tetracycline at 11 and 14 weeks. Animals were sacrificed at 15 weeks and their legs were perfused with a barium compound. Samples were analyzed using plain radiography, Micro CT, brightfield microscopy and fluorescent microscopy. The cross-sectional area of the tibiae were measured using Micro CT.

All statistical calculations were carried out using SPSS Windows Version 14.0 (SPSS Inc., IL, USA). Linear regression was used to test the correlation between canal cross-sectional area and three dependent variables (Micro CT bone volume, Micro CT vessel volume, and bone formation at the osteotomy site). Each of these three linear models was evaluated by calculation of a Pearson correlation coefficient. A two tailed t test was used to test the correlation (a significant correlation was reported when p<0.05).

Results
The volume of bone within the tibial defect site determined using Micro CT was reported as a percentage of the total volume of the defect site. Linear regression analysis of mean percent bone volume as the dependent variable and canal area as the independent variable for the empty treatment group provided a Pearson correlation coefficient of 0.925 (p=0.025) (Fig.1A). The Pearson correlation coefficient for the autograft group was 0.244 (p=0.641).

The volume of blood vessels within the tibial defect site determined using Micro CT was reported as a percentage of the total volume of the defect site. Linear regression analysis of mean percent vessel volume as the dependent variable and canal area as the independent variable for the empty treatment group provided a Pearson correlation coefficient of 0.784 (p=0.117) (Fig. 1B). The Pearson correlation coefficient for the autograft group was -0.146 (p=0.832).

Bone formation rates were reported as the distance between the fluorescent bone labels for each of the 3 time periods: 6 to 9 weeks, 9 to 11 weeks, and 11 to 14 weeks. These measurements were recorded at 4 anatomic sites around the tibial defect (Fig. 2): the endosteum, the cortex, the periosteum and the osteotomy site. Bone formation rate was less within the endosteum, cortex and periosteum with extensive reaming in empty samples. Bone formation rate was less in the cortex with limited reaming in autograft samples.

Discussion
Bone formation within the defect site in samples from the empty group was the result of bone formation at both the proximal and distal osteotomy sites. Bone grew from the osteotomy sites and into the defect. The percent bone volumes in the defect site measured by Micro CT and the bone formation at the osteotomy sites measured by histology are both measuring this growth of bone into the defect. The quantity of this bone growth increased with increasing canal cross-sectional area (i.e., limited reaming improves bone formation in empty samples). Limited reamed empty samples also exhibited greater bone formation rates within their endosteum, cortex and periosteum.

Contrary to findings in the empty samples, bone formation at the osteotomy sites and within the cortex increased with decreasing canal cross-sectional area (i.e., extensive reaming improves bone formation in autograft samples). Vasculature, endosteal bone formation, and periosteal bone formation did not exhibit this relationship.

Our results suggest that the acute management of tibia fractures with bone defects should involve limited intramedullary reaming. Limited reaming may be defined by the cross-sectional area of the tibia in comparison to the cross-sectional area of the reamer. This relationship does not apply when the defect is bone grafted. More extensive reaming may be advantageous in this scenario.

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